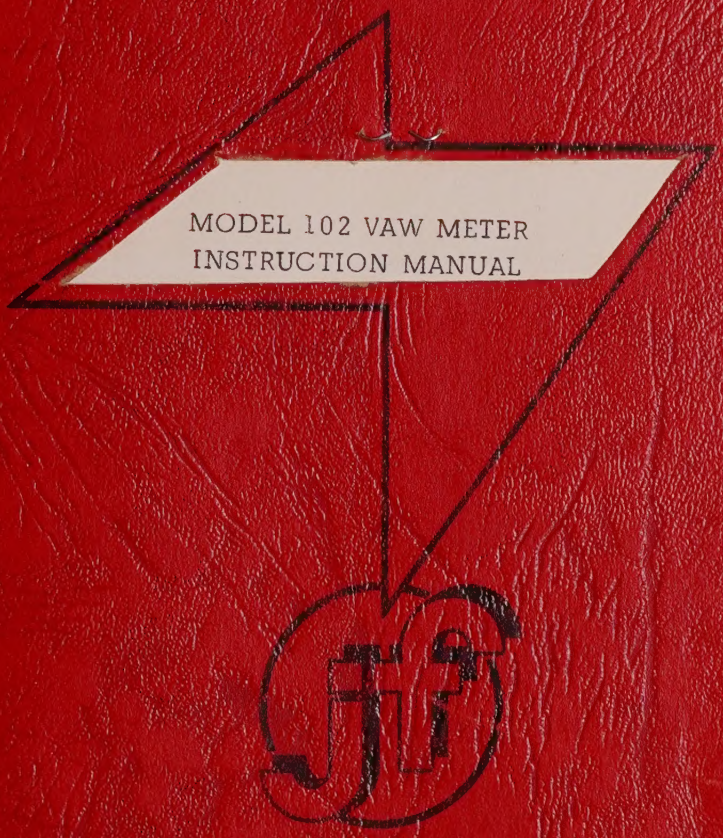
INSTRUCTION MANUAL



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MODEL 102 VAW METER
INSTRUCTION MANUAL

INSTRUCTION MANUAL FOR

jf MODEL 102

VAW METER

SERIAL NUMBER 746 AND ABOVE

MODEL 102 VAW METER

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MODEL 102 VAW METER*

Electrical Specifications

Voltage Ranges:	Nine: 1.5, 3, 6, 15, 30, 60, 150, 300, 600 RMS Volts
Ampere Ranges:	Fourteen: .0015, .003, .006, .015, .03, .06, .15, .3, .6, 1.5, 3, 6, 15, 30 RMS Amperes
Watt Ratings:	Following table is based on unity (1) setting of POWER FACTOR SWITCH. For 0.1 setting of this switch multiply the watt values in the table below by 0.1.

Amps.	1.5V	3.0V	6.0V	15V	30V	60V	150V	300V	600V
.0015	.00225	.0045	.009	.0225	.045	.09	.225	.45	.9
.003	.0045	.009	.018	.045	.09	.18	.45	.9	1.8
.006	.009	.018	.036	.09	.18	.36	.9	1.8	3.6
.015	.0225	.045	.09	.225	.45	.9	2.25	4.5	9.0
.030	.045	.09	.18	.45	.9	1.8	4.5	9.0	18
.060	.09	.18	.36	.9	1.8	3.6	9.0	18	36
.150	.225	.450	.90	2.25	4.5	9.0	22.5	45	90
.300	.45	.9	1.8	4.5	9.0	18	45.0	90	180
.600	.9	1.8	3.6	9.0	18.0	36	90	180	360
1.5	2.25	4.5	9.0	22.5	45	90	225	450	900
3.0	4.5	9.0	18	45	90	180	450	900	1800
6.0	9.0	18	36	90	180	360	900	1800	3600
15.0	22.5	45	90	225	450	900	2250	4500	9000
30	45.0	90.0	180	450	900	1800	4500	9000	18000

Power Factor Range:	Two power factor ranges are provided for the watts scales: One is for unity power factor; the other for 10% (0.1) power factor. More appropriately the 10% power factor range is a provision expanding watt readings by a factor of ten. (See text.)
Frequency Range:	20 to 20,000 cycles per second.
Overall Accuracy:	Within plus or minus 3% of full scale for any reading within rated frequency range.
Volt & Ampere:	In terms of the average value of the full rectified sine wave. Volt and ampere scales are calibrated in RMS values.
Watt Readings:	In terms of VAcosØ. If harmonics are present, watt readings will be the sum of powers due to fundamental and harmonics of voltage and current. There is no waveform error in watts readings for frequencies within rated values.
Meter Calibration:	Selectively reads RMS volts, RMS amperes or watts.
Scales:	All scales are linear.
Input Impedance:	Input resistance is 1 megohm for all voltage ranges. Input capacity is about 25 uufd.
Shunt Drop:	Shunt drop is forty-five millivolts (0.045 v) at full scale current.

* The VAW Meter is protected by United States Patents and the word "VAW" is a registered trade mark.

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Electrical Specifications (Continued)

Overload Capacity:	At least three times, appreciably more on most ranges. Limited by shunt dissipation for current and input circuits for voltage.
Regulated Power Supply:	Line voltage variations from 105 to 125 volts at 60 cps cause less than 0.5% variation in readings. Highly regulated plate supply and regulated filament supply are utilized.
Power Requirements:	Nominal input voltage 117 volts, 60 cps, 135 watts, Line voltage range 105 to 125 volts.
Fuse Rating:	Three amperes.

Mechanical Specifications

Weight:	Twenty-seven pounds.
Dimensions:	Overall size: 15-1/2" wide, 10-1/2" high, 13-1/2" deep.
Finish:	Baked gray leather grain, smooth gray baked enamel on from panel.
Price:	$555.00 standard model; $605.00 rack mounting model; both FOB factory.

The right is reserved, without notice, to make such changes in equipment, design, or components as engineering or manufacturing progress may warrant. Prices subject to change without notice.

INSPECTION

After unpacking the Model 102, it should be carefully inspected for damage received in transit. If damage is found a claim should immediately be made against the carrier. Shunts are packed in the same container as the Model 102. Make certain that all shunts are accounted for before disposing of the shipping container. Check the contents against the packing slip. Reference should be made to the Warranty Section of this instruction manual for the procedure to be followed if any shipping damage has occurred.

INITIAL OPERATION

Plug the power cord from the Model 102 into a suitable source of power rated at a nominal 117 volts, 60 cps. Turn the power switch to "ON" position. The pilot light should glow. If not, look for a blown fuse or open pilot light. If this does not remedy the fault, disconnect the instrument immediately, and look for internal shipment damage.

Allow the instrument to warm for at least five minutes. If the instrument has been brought in from a cold atmosphere and is thoroughly chilled, allow about fifteen minutes for this warm-up. Next set the "VAW" switch (lower right-hand knob) to "W", and adjust "ZERO W" knob to bring the meter pointer to zero. Plug in a shunt of desired rating; connect the circuit to be measured; set the "VOLTAGE RANGE SWITCH" to the desired range; and the instrument is ready for use. WHILE THE OPERATION OF THE MODEL 102 VAW METER IS THIS SIMPLE, PLEASE READ THE REST OF THIS INSTRUCTION BOOK FOR OPERATING DETAILS THAT WILL BE OF MUCH USE TO YOU IN GETTING THE MOST FROM THIS INSTRUMENT.

CONTROLS AND TERMINALS

The following controls and fittings are provided on the Model 102 VAW Meter for use in its operation.

Designation	Location	Function and Remarks
Input terminals marked "H" and "G" (Line side terminals)	Upper left front panel	"H" terminal is to be connected to high side of the POWER SOURCE. "G" terminal is grounded to Model 102 case and is to be connected to ground side of POWER SOURCE.

Designation	Location	Function and Remarks
Output terminals marked "H" and "L" (Load side terminals)	Upper left front panel	"H" terminal is to be connected to one side of LOAD. "L" terminal is to be connected to other side of LOAD. "L" is above ground by shunt drop.
Shunt jacks	Upper left front panel	Shunt plugs into these three jacks with coaxial plug at bottom.
Meter	Upper center front panel	All readings of volts (V), amperes (A) and watts (W) are read on the scales of this meter.
Zeroing knob for watts scales marked "ZERO W".	Upper right front panel	Utilized only in setting meter pointer to zero on watts scales. This "Zeroing" must be done with no signal input to VAW Meter.
Voltage range switch	Lower left front panel	Utilized in setting desired voltage range to any one of full scale values engraved on panel.
Power factor switch marked "POWER FACTOR"	Lower center front panel	Switch has two positions, ".1" and "1". In position "1", full scale watts are equal to the product of shunt rating and voltage range switch setting. For ".1" position full scale watts are equal to that determined at "1" setting multiplied by 0.1 (1/10).
Reading selector switch marked "V", "A", and "W"	Lower right front panel	Causes meter to read selectively volts, amperes, or watts when this switch is respectively in "V", "A", or "W" position.
Power switch and pilot light	Lower right front panel	Power switch turns VAW Meter on in upper position, off in lower position. Pilot light shows power on.
Fuse	Back of case	Fuse holder protrudes from rear of instrument case and is accessible without removal of any screws.

STEP-BY-STEP OPERATION

1. Connect the Model 102 to a nominal 117 volt, 60 cps line and allow at least a five minute warm-up period.

2. Connect lines to the VAW Meter from the power source and from the load. Be sure to connect the high side of the power source to one "H" post. Connect the grounded side of the generator to the "G" post. Connect one side of the load to the other "H" post; the other side of the load to the "L" post. Connections to the "H" post may be interchanged; but connections to the "G" and "L" posts must be connected as herein described, otherwise the wattmeter will read below zero.

3. Select a shunt of suitable rating, and plug it into the shunt jacks.

4. Set the voltage selector switch to the required voltage range.

5. Set the power factor switch to position "1".

6. With no voltage or current from the power source and with the VAW switch set to "W", adjust the meter needle to zero by rotation of the "ZERO W" knob. Do not adjust this knob in the presence of any input since this may not produce a true "W ZERO".

7. Cause power to flow from the generator to load. Read values of load voltage, load current, and load power, by successively rotating the "VAW" switch through "V", "A", and "W" positions.

8. If the "W" (watts) readings are less than 10% of full scale, throw the "POWER FACTOR" switch to the ".1" position. This will cause the deflection of the meter needle on watts scales to be increased by a factor of ten. Under this condition the multiplier of 0.1 must be used with indicated watts readings. Note that this feature should not be used to increase "W" readings in lieu of using a shunt which will give as near a full-scale current as possible. This will insure the best accuracy.

9. Note that with the "POWER FACTOR" switch in the "1" position, the value of the full-scale watt arc is the product of the shunt rating times the setting of the voltage range switch. For example, assume that a .006 ampere shunt is plugged in and that the voltage switch is set to 6 volts. Full scale watts are then (.006) (6) or .036. The scale, amongst other markings, is marked in 36 at full scale. The scale is thus direct reading in significant figure to which must be applied a multiplying factor of .001.

10. Note that with the "POWER FACTOR" switch set in the ".1" position the value of the full scale watts is determined in step 9 above but with an additional multiplier of 0.1 (1/10) applied to the watt readings. Using the above example, the full scale watts would be (.006) (6) (.1) or .0036.

DETAILS OF OPERATION

As in any instrument, certain precautions must be observed in the operation of Model 102. First, the "G" post is connected to the case electrically. If, for some reason, the external lead connected thereto by the user is above ground, or above the potential of surrounding objects, the case likewise will be above ground or such objects. If this difference in level is sufficient to constitute a personnel hazard, adequate precautions must be taken in operating the Model 102 to prevent accidental shock. Such operation is not recommended.

The Model 102 with its ability to act as "a very low power factor wattmeter", that is, its ability to read power in highly reactive loads, represents a very high sensitivity in power measuring equipment. Consequently, the "POWER FACTOR" switch should be kept in the unity or "1" position, except when actually needed in the 10% or ".1" position. If the watt reading is 10% or less of full scale, when the "POWER FACTOR" switch is in the unity (1) position, then it is permissible to throw this switch to the .1 position. It is always, also, well to check all three readings ("V", "A", and "W") to see that they do not exceed full scale before taking any readings. This will prevent overload errors.

NOTE THE FOLLOWING PARAGRAPHS. The Model 102 is not a compensated type of wattmeter owing to its multiplicity of ranges. (There is a maximum of 252 full scale values of watts ranges.) Without compensation, the wattmeter must inherently read either the power consumed in the potential circuit or the power consumed in the shunt. It is possible to omit one of these, but not both, as far as readings of watts are concerned in an uncompensated wattmeter. The choice is usually based on the minimum loss element or the one whose consequent error contribution will have to be least often taken into account.

In the Model 102 the shunt loss is read by the wattmeter. The input circuit for the Model 102 is as shown below along with the normally used external connections.

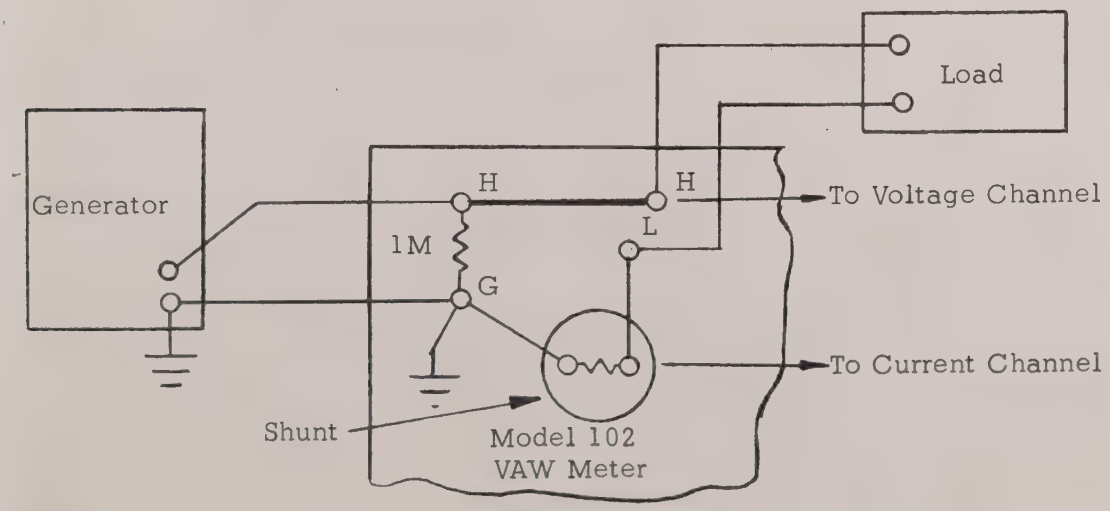


FIGURE I.

Corrections for shunt loss must be made at low voltage ranges for reading low power factor watts accurately on the Model 102. This importance is greatest at the lowest voltage ranges and disappears for the upper voltage ranges. It is of little importance on the voltage readings. The shunt drop is constant for any shunt, for a given percentage of rated current since at rated current for any shunt, the shunt drop is .045 volt (45 millivolts). The resistance of any shunt may be determined by dividing .045 volt by the shunt rated current. Thus the following values are derived:

TABLE I

Shunt Rating Amperes	Shunt Resistance Ohms	Shunt Rating Amperes	Shunt Resistance Ohms
.0015	30	.3	.15
.003	15	.6	.075
.006	7.5	1.5	.03
.015	3	3.0	.015
.03	1.5	6.0	.0075
.06	.75	15.0	.003
.15	.3	30.0	.0015

Since the Model 102 reads current in amperes flowing to the load, it is obvious from Figure 1 that this current also flows through the shunt. Thus, it is always possible to calculate the effects of the shunt drop. The voltage drop of the shunt is found as follows:

$$\text{Shunt drop in volts} = \frac{(\text{"A" reading})(.045)}{\text{Shunt rating}} = (\text{"A" reading})(\text{shunt resistance})$$

The power loss in the shunt is found as follows:

$$\text{Shunt loss in watts} = I^2R = (\text{"A" reading})^2(\text{shunt resistance})$$

(All "A" values are in amperes, and shunt resistance is in ohms)

Thus the voltage readings can be corrected for shunt drop by adding this drop to the voltage "V" actually read. This will be seen to be a small error, even for the lowest scale of 1.5 volts, since at full-scale current it can be only .045 volts or .3% of full scale. At the 3 volt range it is only .15% of full scale, at the 6 volt range .075%, etc. The watt readings are not appreciably affected by shunt loss for the unity setting of the "POWER FACTOR" switch, but they will be very appreciably affected for the 10% setting of the "POWER FACTOR" switch, for the low voltage ranges. The shunt loss watts, as computed above, should be subtracted from the value of watts read. To illustrate, let us assume that the voltage range switch is on the 1.5 volt setting, that a .006 ampere shunt is in use, and that the "POWER FACTOR" switch is in the .1 position. Also, assume that full scale current, or .006 ampere, is indicated. The shunt resistance is 7.5 ohms. The shunt loss is (.006)(.006)(7.5) or .00027 watt. The full-scale watt value is

(.006)(1.5)(.1) or .0009 watt. Thus, the shunt loss is a very appreciable portion of the watt scale, and it must be subtracted from the watts read on the scale. In this case the shunt loss is 30% of the full-scale value. If the "POWER FACTOR" switch had been in the unity or "1" position, the shunt loss would have been only 3% of full scale watts. Or if the voltage range switch setting had been 15 volts, the shunt loss would also have been only 3% of the full scale watts. For other voltage settings, the relative values of shunt loss to full scale watts are proportional for the same current. As the current is decreased from full-scale value, whatever the shunt in use, and as the voltage range setting is increased, the shunt loss correction rapidly becomes smaller. Either a quick calculation as described herein or familiarity with the Model 102 readily will indicate whether to ignore the shunt loss or not.

Table II below has been prepared to summarize the voltage and power corrections to be applied as a function of voltage range switch setting. Note that the table is prepared for full-scale values of current and that the shunt voltage drop at full-scale current is .045 volt.

TABLE II

(1) Voltage Range Switch Setting, Volts "V"	(2) % error in voltage reading caused by shunt drop*	(3) % of full scale watt reading due to shunt loss. "Power Factor Switch" at .1**	(4) Same as (3) but for "Power Factor Switch" set at 1.0**
1.5	.3%	30%	3%
3	.15%	15%	1.5%
6	.075%	7.5%	.75%
15	.03%	3%	.3%
30	.015%	1.5%	.15%
60	.0075%	.75%	.075%
150	.003%	.3%	.03%
300	.0015%	.15%	.015%
600	.00075%	.075%	.0075%

* Error causes reading to be larger than correct value by percentage shown. For less than full-scale current error is to be multiplied by $\frac{\text{Actual Current}}{\text{Full-Scale Current}}$.

** Note that these percentages obtain for any voltage from zero plus to 100% of full scale deflection and they depend only on "Voltage Range Switch" setting and on the current being at full scale. If the current is less than full scale, then these values are reduced by $\left(\frac{\text{Actual Current}}{\text{Full-Scale Current}}\right)^2$.

Sometimes it may be desirable to read the power flowing to a load, one side of which is grounded. Under this condition, the generator may be found to be either grounded or ungrounded. If the latter is the case, satisfactory operation may be realized by insulating the Model 102 case from any conducting path other than the connecting leads. This will depend on the level of operation and the effect of common capacities between the load and generator and the Model 102, these capacities arising through their respective housings and through their power supply transformers, which are commonly connected to the same power system. A way of eliminating this error is by the use of the connections shown in the following sketch, Figure 2.

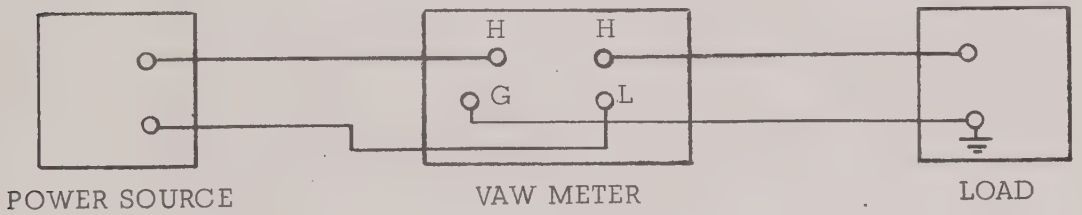


FIGURE II.

If both generator and load have one side grounded, it may be desirable to use the circuit shown in Figure 3. The transformer should have insufficient capacity between primary and secondary to short, appreciably, the shunt. The transformer has been placed on the generator side so that its losses will not be read by the wattmeter. Where the "G" and "L" posts are interchanged, it will be necessary to get into the Model 102 and reverse two connections, as noted on the circuit diagram in this manual, in order to get up-scale watt readings.

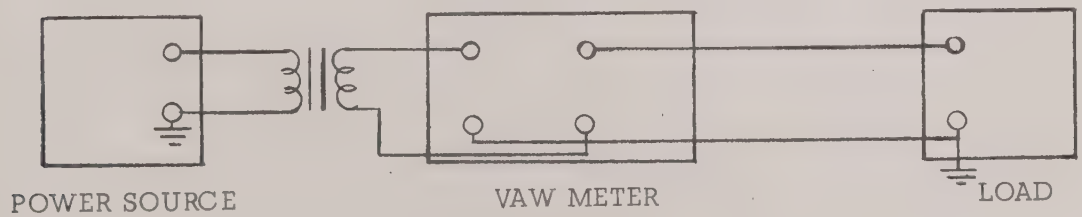


FIGURE III.

There is inherently no waveform error in the watt readings presented on the VAW Meter assuming no phase or amplitude distortion in the VAW Meter amplifiers, or other residual errors such as indicating instrument non-linearities, etc. Practically, the absence from waveform error is limited by the amplifiers. In the

Model 102 the amplifiers have a response which is flat in amplitude and they introduce no phase shift over a frequency range in excess of 20 to 20,000 cps. Hence the Model 102 will indicate accurately the power being delivered by non-sinusoidal periodic waves of voltage and current where the fundamental frequency is 20 cps or greater and where the highest harmonics of voltage and/or current of interest do not appreciably exceed 20 kc. Hence the watt readings will be the sum of the powers due to the individual harmonic quantities. That is, the "W" readings will be $W = V_n A_n \cos\phi_n$ where "n" denotes corresponding harmonic quantities. While no practical limit can be given here for the general case, it is obvious that a wave with 20 kc fundamental, and possessing appreciable percentages of much higher harmonics, error in actual total power may derive due to failure of the Model 102 amplifiers to preserve phase relations between the various harmonics and also due to modification of the amplitudes of the harmonics. For usual cases, harmonics or frequencies as high as 40 kc will be handled with only several percent increase in error. The error is greatest for the low power factor watt ranges where very small changes in phase angle may affect the readings appreciably. You should note that at full-scale values on the 10% power factor range the total scale arc represents only about 6 degrees, or the angle between current and voltage is 84 degrees. Thus the deflection of each ten percent of "W" scale, under this condition, is equal to .6 degrees or 36 minutes of arc. (These angles are approximate; see trigonometric tables for more accurate values).

The volt and ampere readings are obtained by separately rectifying signals from the voltage and current channels in full-wave manner and applying the resultant signal-proportional direct voltage to the panel meter. Using full-wave rectification gives the minimum wave-form error compared with half-wave or peak methods. While the error resulting from distorted waves is dependent on magnitude and phase of the harmonics, it is helpful to know the maximum value such errors may reach. Table II illustrates several cases of reading extremes for several percentages of harmonics. Note that the "V" and "A" channels of the Model 102 are calibrated in terms of RMS value of a sine wave. Note, also, from the circuit diagram, that a rectifying circuit is incorporated in the feedback path. This results in high order linearity of meter readings as well as improved long term accuracy of calibration.

The meter scale is provided with a scale marked "Cosϕ". This scale thus can be used to read power factor directly, or it can be used to read directly in terms of percentage of full scale when absolute values are not required. Its primary purpose is for the former use. To use this scale, set (by suitable means external to the Model 102 usually) the "V" and "A" deflections to full-scale value. Switch to "W", which will then read directly in terms of Cosϕ. The full-scale value of the reading will be 100%, if the "POWER FACTOR" switch is set to unity or "1"; and it will be 10%, if this switch is set to ".1". When "V" and/or "A" cannot be set to full scale conveniently, the Cosϕ scale reading can be multiplied by

the inverse of the product of the fraction of full scale of the "V" and "A" readings. Thus if both these readings are half scale, the full scale length of CosØ is reduced to one-fourth of the actual scale, and the CosØ readings must be multiplied by the inverse of (1/2)(1/2) or 4.

TABLE III

% Harmonic	Actual RMS Value	Model 102 "V" or "A" Reading	Peak Meter Reading
0	100	100	100
10% 2nd	100.5	100	90-110
20% 2nd	102	100-102	80-102
50% 2nd	112	100-110	75-150
10% 3rd	100.5	96-104	90-110
20% 3rd	102	94-108	82-120
50% 3rd	112	90-116	108-150

CIRCUIT DESCRIPTION

There are two main amplifier channels in the Model 102. One is for amplifying a voltage proportional to circuit voltage, the other is for amplifying a voltage proportional to circuit current. The output of each of these channels can be rectified and supplied separately to a direct current meter whereby readings of circuit voltage or circuit current are effected. The voltage channel may have its gain adjusted by predetermined steps, by the "Voltage Range Switch", to give a total of nine different full scale values which have been selected to give the best coverage of the usual voltages encountered. The current channel effectively has its gain adjusted in predetermined steps by the fourteen standard shunts available. For reading watts, the outputs of the two amplifier channels are suitably combined and applied to a multiplier, whose output is proportional to the product of these two outputs and the cosine of their relative phase displacement in degrees. The multiplier contains no thermocouples, rectifiers, tubes, or moving parts. It is sealed in a small can and liquid filled. Normally, no replacement is ever required for this unit. It should not be tampered with; such voids any guarantee on this instrument. Should it fail, it will be replaced free of charge, when the Model 102 is returned prepaid to us, if it has not been disturbed in any manner.

The voltage channel is composed of V1 and V9 (see schematic diagram). Switch S1 is the voltage range switch, which provides known attenuation of the voltage input. Re1 and Re2 rectify the amplified signal which is applied to the meter "M" through switch S2, the "VAW" switch.

The current channel is composed of tubes V4, V5, and V9 and performs in a manner similar to the voltage channel, with selection of appropriate connections being effected by the switch S2 being put in the "A" position.

For reading watts, tube V2 adds the current and voltage signals. Tubes V6 and V7 subtract these two signals. These sum and difference signals are applied to two cathode followers, respectively, which apply the sum and difference signals to the multiplier. The output of the multiplier is selected by switch S2 in position "W", to apply the output of the multiplier to the panel meter and thus read watts. The power factor ranges are selected by switch S3, which modifies the gain of the adding and subtracting tubes.

Filaments of several of the amplifier tubes are supplied a stabilized voltage by a ballast tube V10. This results in improved stability of readings against line voltage. This also materially improves the stability of the "W" zero against this condition.

Tubes V11 through V14 act as a stabilized power supply of very low internal impedance and high regulation. These features serve to minimize effects of changing line voltage and also help to stabilize the amplifiers to provide high fidelity amplification of signals in both amplitude and phase, which is extremely essential to this instrument.

It should be noted that in several places the circuit is equipped with "trimmer" capacitors or resistors. These are usually associated with the precision-type film resistors. You are cautioned against disturbing these components during maintenance. Their being moved may result in impairing the accuracy of watt readings in the 5 kc to 20 kc region.

MAINTENANCE

While the tubes in the Model 102 are conservatively used and will usually be found to require very infrequent replacement, their failure will nevertheless be experienced from time to time. The original tubes in the Model 102 are not selected by means other than those normally employed to reject off-tolerance or otherwise defective tubes. Consequently, tube replacement offers no appreciable problem. This does not infer that any tube may be used for replacement. The most reliable guide in this respect is satisfactory instrument operation. Poor amplifier tubes (low filament-to-cathode insulation and tubes with radically different constants from the characteristics of the type) will cause reading errors. The former will usually evidence itself in some meter deflection in the absence of any input. The latter may affect reading accuracy in spite of the large amount of negative feedback employed. Tubes V3 and V8 must be near enough alike in characteristic to allow P5, "ZERO W" control, to zero the watt scales. Failure of any range to read on application of a signal will usually be due to a blown

fuse, failure of an amplifier tube, or failure of the rectifier tube, or regulator tubes V14 and V13, respectively. Failure of V11 or V12 will result in erratic operation and may cause oscillation of the meter pointer. When replacing any of the power supply system tubes, the output voltage of the regulator should be checked and found to be 245 volts, adjusting P8 as needed. V10 should glow only for a few seconds after turning the Model 102 on. After that, it should be dark. Its output voltage should be about 6.3 volts. Failure of V10 will make it difficult or impossible to zero "W". Also, instrument calibration will be impaired.

Keep the instrument clear by wiping it out when necessary. Do not restrict its natural ventilation. Do not turn things while looking for misoperation - most failures are simple things and can be found with a little patience. Take time to measure voltage, and simply observe rather than twist controls in looking for trouble. Failure to observe this will usually result in impairing the accuracy of the instrument, since the large combinations of readings found on the 102 make it somewhat difficult to recalibrate with the usual facilities to the degree of accuracy with which it was calibrated at the time of its manufacture.

In any event, the replacement of tubes or other components warrants a check of accuracy. Should the accuracy be found diminished after tube replacement, it is suggested that several tubes be tried, from which the best one may be selected for use.

TROUBLE SHOOTING CHART

TABLE IV

Symptom	Possible Cause	Remedy
(A) Instrument not operating. Pilot light not on.	(1) Blown line fuse.	(1) Replace fuse.
	(2) Open or shorted transformer.	(2) Check transformer, replace if defective.
	(3) Defective line cord or switch.	(3) Replace or repair.
(B) Instrument not operating. Pilot light on.	(1) V14, V13, V12 or V11 defective.	(1) Replace one by one.
	(2) V10 defective.	(2) Look for visible redness or open filament. Replace if red or open. This can also be checked by measuring filament voltage, e.g., pins 2 and 8 on V3 and V8 should be 6 to 6.4 volts.
(C) Watt range will not zero.	(1) V3 or V8.	(1) Replace one or both tubes selecting tubes which will allow zeroing of wattmeter with "Zero W" setting at about center of its rotation.
	(2) V10.	(2) Check V10 for open filament or for excessive drop (filament red 5 minutes or more after warmup or voltage at V3 or V4 below 6 volts on pins 2 and 8).
(D) Oscillation of meter pointer.	(1) Low or high line voltage.	(1) Measure line voltage, should be 115 to 120 volts.
	(2) Badly fluctuating line voltage.	(2) Voltage dips may go below or above d-c regulator range or fluctuations may be in excess of transient response capabilities of power supply regulator. Use more stable line voltage.
	(3) V14, V13, V12, V11.	(3) Selectively replace V14, V13, V12, or V11.
	(4) Setting of P8.	(4) Reset P8 if regulated output voltage is not between 240 and 247 volts. Reset to 245 volts. P8 is located on rear terminal board under chassis.

Symptom	Possible Cause	Remedy
(E) No voltage reading. "A" readings okay.	(1) V1. (2) Resistors on switch S1.	(1) Replace V1. (2) Check for value and replace with appropriate resistors.
(F) No current reading. "V" readings okay.	(1) V4, V5. (2) Defective shunt.	(1) Replace V4 or V5. (2) Check shunt or shunt jacks for short or poor connection.
(G) No "V" or "A" readings. "W" readings okay.	(1) V9. (2) Re1 or Re2.	(1) Replace V9. (2) Replace Re1 and Re2.
(H) No "W" reading. "V" and "A" reading okay.	(1) V3, V8. (2) V2, V6, V7.	(1) Replace V3 and V8. (2) Replace V2, V6, or V7.
(I) "V", "A", or "W" readings out of calibration.	(1) For "V" reset P2 located at back right of chassis accessible from top. (2) For "A" reset P1 located near 6SJ7 at left front of chassis accessible from top. (3) For "W" at unity power factor reset P4 located at right front of chassis behind Zero "W" knob accessible from top. (4) For "W" at .1 power factor reset P6 located immediately behind meter accessible from top.	

To correct calibration, proceed as follows:

(1) Use sine wave oscillator at about 1,000 cps; plug in, for example, .006 ampere shunt; set voltage range switch to 6 volts; set Power Factor Switch to 1; plug in accurate 1,000 ohm load. Set "W" to zero with no signal from oscillator. Monitor current from oscillator with thermo-ammeter (Weston Model 622, 0 - 10 ma, for example).

(2) Adjust oscillator output to give 6 ma on the thermo-ammeter. This will give 6 volts across load. Adjust P2 to make "V" read full scale.

(3) Set "V A W" switch to "A" and adjust P1 to make "A" read full scale.

(4) Set "V A W" switch to "W" and adjust P4 to make "W" read full scale.

(5) Remove thermo-ammeter and 1,000 ohm load. In its place put load of 92.5 ohms in series with about .25 mfd Mica capacitor. Set Power Factor Switch to .1. Adjust oscillator input to give full scale current as read on the "A"

scale of the Model 102. Be sure "A" reading is set right on full scale. ("V A W" switch at "A"). Now set "V A W" switch to "W" and set P6 to make "W" read full scale.

(6) Note that foregoing is an adjustment procedure adequate for most field checking. If extreme recalibration is required or extensive repairs have been made or if calibration at frequency extremes is required, it is suggested that the Model 102 be returned to the factory.

MODEL 102

LIST OF REPLACEABLE PARTS

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
C1A,B C2A,B C3A,B C4A,B	Capacitor, electrolytic 20/20 mfd, 450 v	CE5
C5,6	Capacitor, electrolytic 500 mfd, 25 v	CE2
C7	Capacitor, electrolytic 2000 mfd, 6 v	CE6
C8	Capacitor, electrolytic 200 mfd, 6 v	CE30
C10, 14, 16, 22, 26, 27	Capacitor, paper .22 mfd, 400 v	CP2
C11, 13, 15, 19, 21, 23, 25	Capacitor, paper .1 mfd, 400 v	CP4
C12	Capacitor, electrolytic 20 mfd, 250 v	CE40
C28	Capacitor, electrolytic 16 mfd, 450 v	CE3
C17	Capacitor, mylar .22 mfd, 400 v	CP19
C18	Capacitor, electrolytic 40 mfd, 450 v	CE4
C20, 24A, 24B	Capacitor, paper 1 mfd, 400 v	CP8
C40, 41, 46, 47, 48, 49, 50	Capacitor, ceramic, variable 7-35 mmfd, 500 v	CA3
C42	Capacitor, ceramic, fixed 3 mmfd, 500 v	CT10
C43, 51	Capacitor, ceramic, fixed 39 mmfd, 500 v	CT15
C44	Capacitor, ceramic, fixed 100 mmfd, 500 v	CT12

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
C45	Capacitor, ceramic, fixed 82 mmfd, 500 v	CT11
R3,6,20,28, 45A,45B	Resistor, composition 22 k, 10%, 1 w	GB2231
R4,24	Resistor, composition 10 k, 10%, 1 w	GB1031
R5	Resistor, composition 10 m, 10%, 1/2 w	EB1061
R7,19,23,27	Resistor, composition 220 k, 10%, 1/2 w	EB2241
R8,18,21,29	Resistor, composition 100 k, 10%, 1 w	GB1041
R10,17,30,43, 50A,50B	Resistor, composition 33 k, 10%, 1 w	GB3331
R11,31,37,44, 48,49	Resistor, composition 470 k, 10%, 1/2 w	EB4741
R12,32	Resistor, composition 150 k, 10%, 1/2 w	EB1541
R13,33	Resistor, composition 18 k, 10%, 1/2 w	EB1831
R14	Resistor, composition 2.2 m, 10%, 1/2 w	EB2251
R15D, 52D	Resistor, deposited carbon 75Ω, 1%, 1/2 w	DR23
R25	Resistor, composition 100 k, 10%, 1w	GB1041
R34,35	Resistor, composition 18 k, 10%, 1 w	GB1831
R36D	Resistor, deposited carbon 3.89 k, 1%, 1/2 w	DR414

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
R38,39	Resistor, composition 560Ω, 10%, 1/2 w	EB5611
R40	Resistor, composition 1.5 k, 10%, 1 w	GB1521
R41	Resistor, composition 15Ω, 10%, 1 w	GB1501
R42	Resistor, composition 82 k, 10%, 1 w	GB8231
R46	Resistor, composition 330 k, 10%, 1 w	GB3341
R47	Resistor, composition 270 k, 10%, 1 w	GB2741
R51	Resistor, composition 4.7 k, 10%, 1 w	GB4721
R53D	Resistor, deposited carbon 50Ω, .1%, 1/2 w	DR22
R54,55	Resistor, composition 5.6 k, 10%, 1/2 w	EB5621
R56	Resistor, wirewound 150Ω, 5%, 10 w	R150WA
R100	Resistor, deposited carbon 900 k, 1%, 1/2 w	DR622
R101	Resistor, deposited carbon 90 k, 1%, 1/2 w	DR512
R22D,102	Resistor, deposited carbon 10 k, 1%, 1/2 w	DR51
R103	Resistor, deposited carbon 1.5 k, 1%, 1/2 w	DR44
R104	Resistor, deposited carbon 5.44 k, 1%, 1/2 w	DR410
R105	Resistor, deposited carbon 1.845 k, 1%, 1/2 w	DR45

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
R106	Resistor, deposited carbon 135Ω, 1%, 1/2 w	DR31
R107,108,115 116,118	Resistor, deposited carbon 50 k, 1%, 1/2 w	DR59
R109,114	Resistor, deposited carbon 40 k, 1%, 1/2 w	DR57
R110,113	Resistor, deposited carbon 135 k, 1%, 1/2 w	DR65
R111,112	Resistor, deposited carbon 200Ω, 1%, 1/2 w	DR32
R117	Resistor, deposited carbon 52.14 k, 1%, 1/2 w	DR510
P1,2,3	Potentiometer, wirewound 1 k, 10%, 2 w	P1000A
P4,6	Potentiometer, wirewound 75Ω, 10%, 2 w	P75A
P5,8	Potentiometer, wirewound 5 k, 10%, 2 w	P5000A
P9	Potentiometer, wirewound 500Ω, 10%, 1/4 w	P500TB
V1,9	Tube, dual triode Type 6SN7	6SN7
V2,5,6,7	Tube, pentode Type 6AC7	6AC7
V3,8	Tube, power pentode Type 6V6	6V6
V4	Tube, pentode Type 6SJ7	6SJ7
V10	Tube, current regulator Type 22-4	22-4
V11	Tube, voltage regulator Type OD3	OD3

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
V12	Tube, dual triode Type 6SL7	6SL7
V13	Tube, power dual triode Type 6080	6080
V14	Tube, rectifier Type 5Y3	5Y3
RE1,2	Diode, germanium Type 1N51	X42
M1	Meter, 500 u amp. d-c with special scale	M2
S-CAN	Wattmeter squaring element special	X260
L1	Reactor, filter, 7 h, 140 ma	TC2
T1	Transformer, power	T1A
S1	Switch, rotary 4 pole, 9 pos., 4 deck	SR1
S2	Switch, rotary 3 pole, 3 pos., 1 deck	SR4
S3	Switch, rotary 3 pole, 2 pos., 1 deck	SR4
S4	Switch toggle, SPST 115/230 v, 3 amp.	ST5
F1	Fuse, 3 ampere	F3
L1	Pilot lamp, 6-8 v, Type 44	X34

CIRCUIT SYMBOL	DESCRIPTION	FLUKE STOCK NO.
	Fuse holder	X12
	Pilot light	X14
	Input jack	X31
	Knob, 2 inch, pointer	X232
	Knob, 1-1/2 inch, pointer	X234
	Cable, power 3 conductors #18	X27H
	Bushing, strain relief	X212
	Foot, rubber mounting	X224
	Handle, case carrying	X2062

WARRANTY

The JOHN FLUKE MFG. CO., INC. warrants each instrument manufactured by them to be free from defects in material and workmanship. Their obligation under this Warranty is limited to servicing or adjusting an instrument returned to the factory for that purpose, and to making good at the factory any part or parts thereof; except tubes, fuses, choppers and batteries, which shall, within one year after making delivery to the original purchaser, be returned by the original purchaser with transportation charges prepaid, and which upon their examination shall disclose to their satisfaction to have been thus defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before work is started, if requested.

If any fault develops, the following steps should be taken.

1. Notify the John Fluke Mfg. Co., Inc., giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.

2. On receipt of the shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the Warranty.

SHIPPING

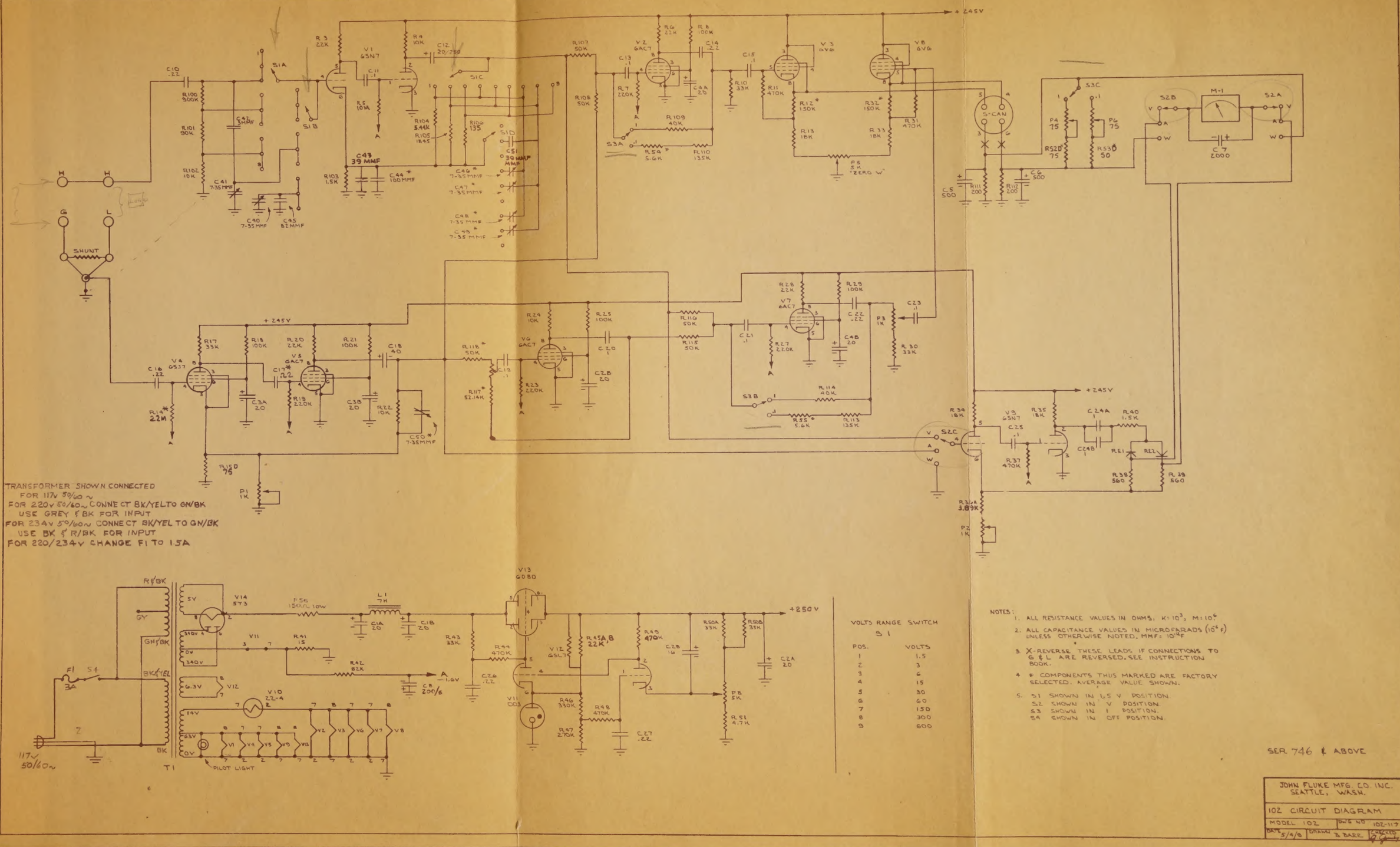
All shipments of John Fluke Mfg. Co., Inc. instruments should be made via Railway Express prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be thoroughly inspected immediately upon receipt. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to John Fluke Mfg. Co., Inc. Upon receipt of this report you will be advised of the disposition of the equipment for repair or replacement. Include the model number, type number, and serial number when referring to this instrument for any reason.

The John Fluke Mfg. Co., Inc. will be happy to answer all application questions which will enhance your use of this instrument. Please address your requests to:

JOHN FLUKE MFG. CO., INC., P. O. BOX 7428, SEATTLE 33, WASHINGTON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V3 6V6
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V5 6AC7
V6 6AC7
V7 6AC7
V8 6V6
V9 6SN7
V10 22-4
V11 CD3
V12 6SL7
V13 6080
V14 5Y3
VI2
T1
F1 3A
S4
117V 50/60~
PILOT LIGHT
TRANSFORMER SHOWN CONNECTED
FOR 117V 50/60 ~
FOR 220V 50/60~ CONNECT BK/YEL TO GN/BK
USE GREY & BK FOR INPUT
FOR 234V 50/60~ CONNECT BK/YEL TO GN/BK
USE BK & R/BK FOR INPUT
FOR 220/234V CHANGE F1 TO 1.5A
VOLTS RANGE SWITCH
S1
POS. VOLTS
1 1.5
2 3
3 6
4 15
5 30
6 60
7 150
8 300
9 600
NOTES:
1. ALL RESISTANCE VALUES IN OHMS, K=10³, M=10⁶
2. ALL CAPACITANCE VALUES IN MICROFARADS (10⁻⁶F) UNLESS OTHERWISE NOTED. MMF=10⁻¹²F
3. X-REVERSE THESE LEADS IF CONNECTIONS TO G & L ARE REVERSED. SEE INSTRUCTION BOOK.
4. * COMPONENTS THUS MARKED ARE FACTORY SELECTED. AVERAGE VALUE SHOWN.
5. S1 SHOWN IN 1.5 V POSITION.
S2 SHOWN IN V POSITION.
S3 SHOWN IN 1 POSITION.
S4 SHOWN IN OFF POSITION.
SER 746 & ABOVE
JOHN FLUKE MFG. CO. INC.
SEATTLE, WASH.
102 CIRCUIT DIAGRAM
MODEL 102
DWG NO 102-117
DATE 5/4/8
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